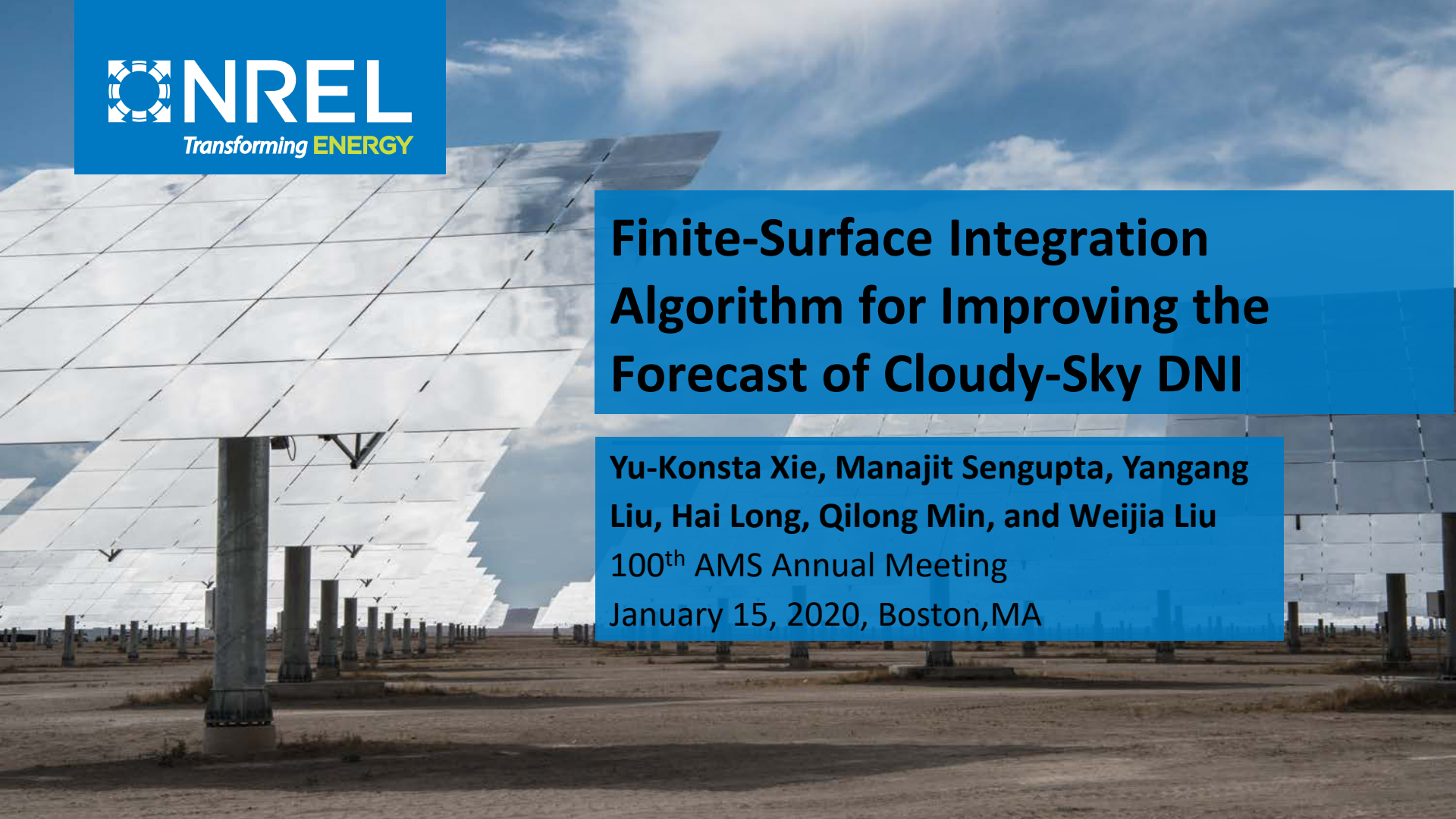


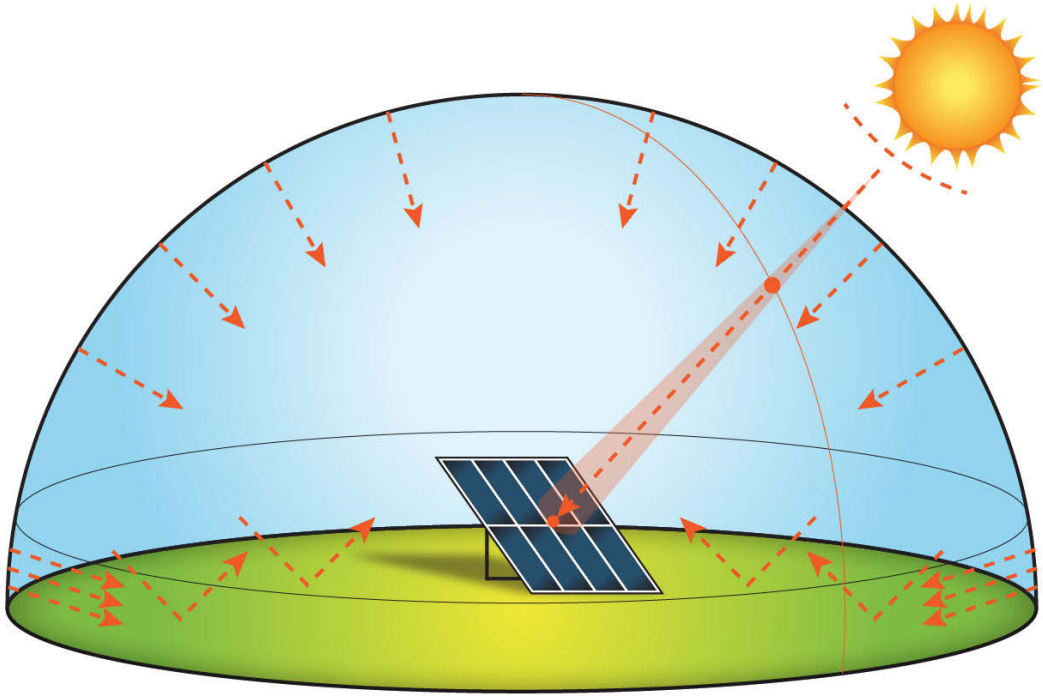
NREL
Transforming ENERGY

Finite-Surface Integration Algorithm for Improving the Forecast of Cloudy-Sky DNI

Yu-Konsta Xie, Manajit Sengupta, Yangang Liu, Hai Long, Qilong Min, and Weijia Liu

100th AMS Annual Meeting
January 15, 2020, Boston,MA

What Is Direct Normal Irradiance (DNI)?



Direct radiation is often assumed along a narrow beam straight from the sun.

The ISO-9488 standard defines direct irradiance by the quotient of the radiant flux on a given plane receiver surface received from a small solid angle centered on the sun's disk to the area of that surface. The circumsolar region is recommended to be approximately 100 times larger than the average sun disk.

The Significance of DNI in Solar Energy

PV panels track the sun to receive more DNI. DNI accounts for a large portion of the solar energy from PV.

DNI is particularly important in forecasting the performance of concentrating solar power (CSP) systems.

Photos by Dennis Schroeder, NREL 31446 and NREL 46173

How to Simulate DNI?

Lambert Law

Computes radiation in an infinite-narrow beam. **Does not consider angular extent of the solar disk.**

Empirical Model

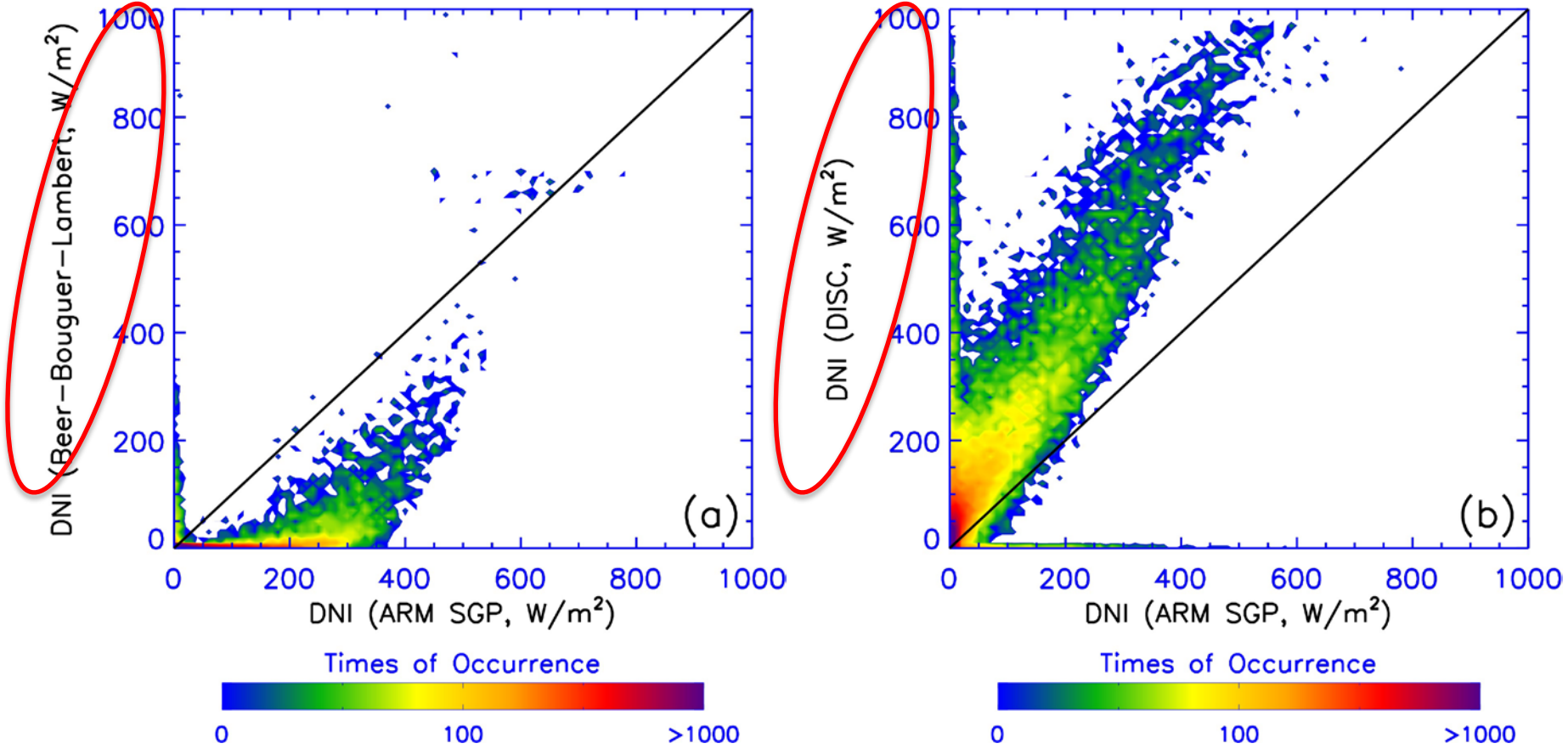
Link between long-term GHI and DNI observations. **Depend on data availability at locations and time.**

Physical Model

Numerically solves the radiative transfer equation. **Time consuming.**

Photo by Dennis Schroeder

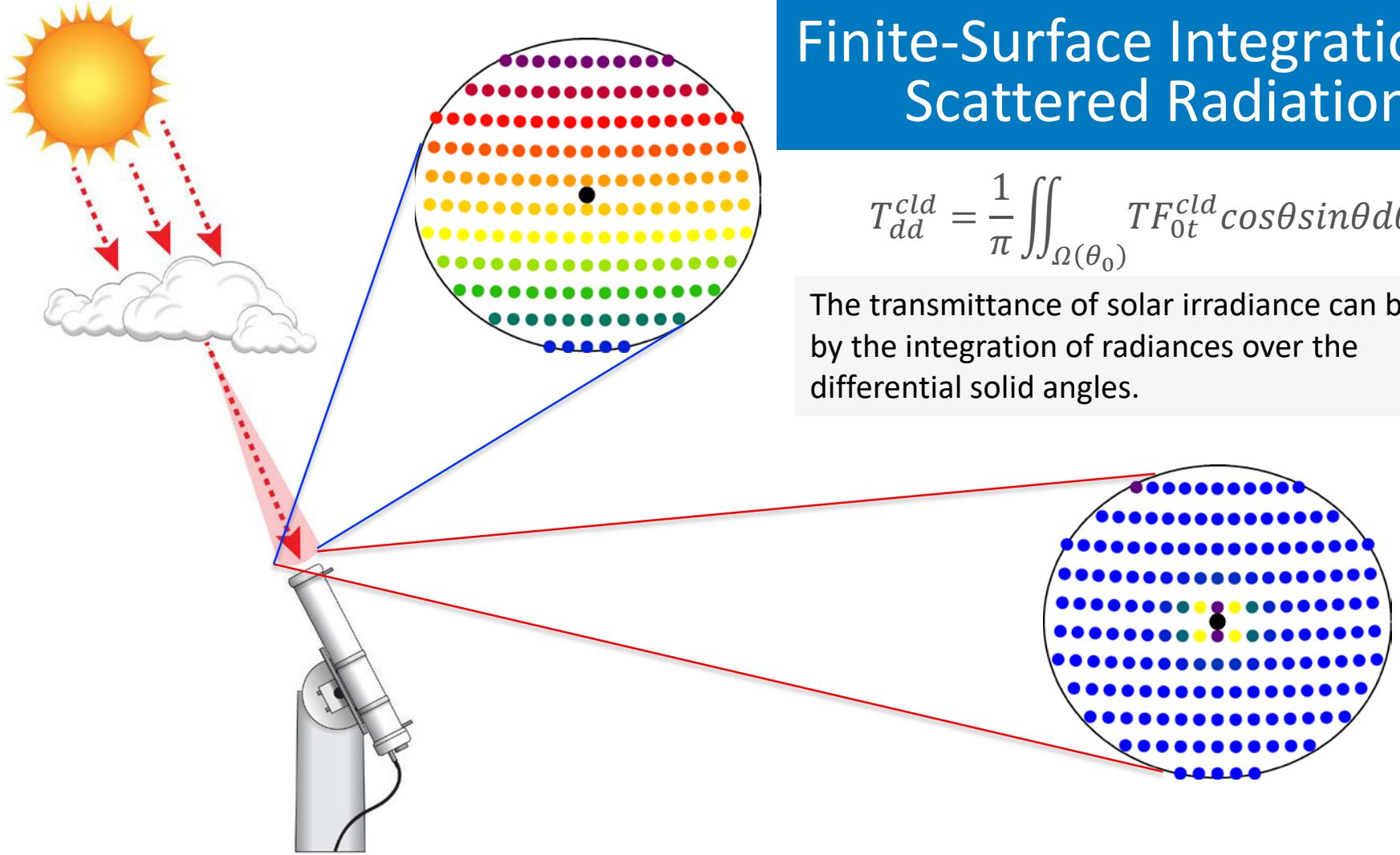
DNI Has Dramatic and Unexpected Bias in Cloudy-Sky Conditions



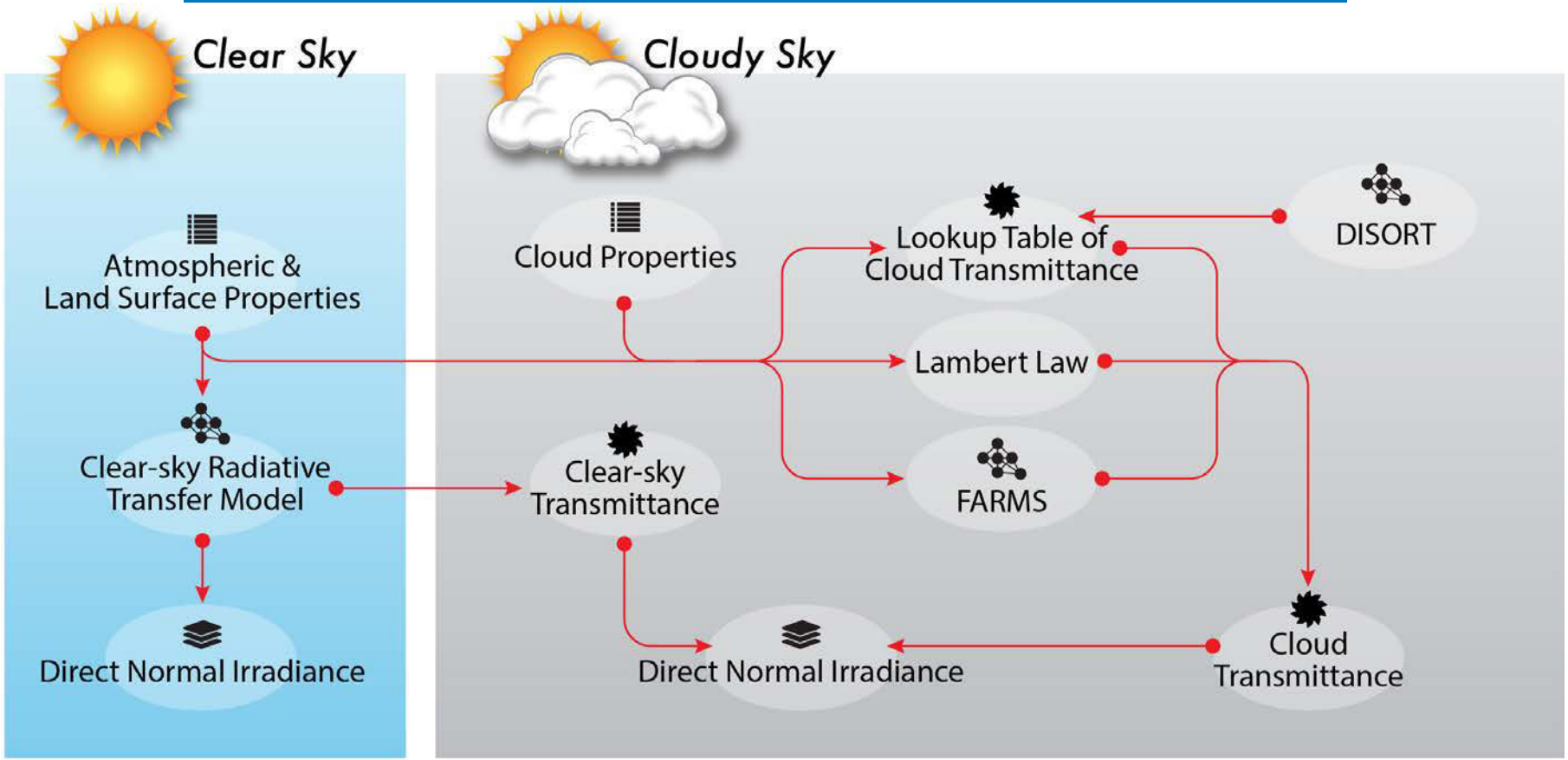
Finite-Surface Integration of Scattered Radiation

$$T_{dd}^{cld} = \frac{1}{\pi} \iint_{\Omega(\theta_0)} TF_{0t}^{cld} cos\theta sin\theta d\theta d\varphi$$

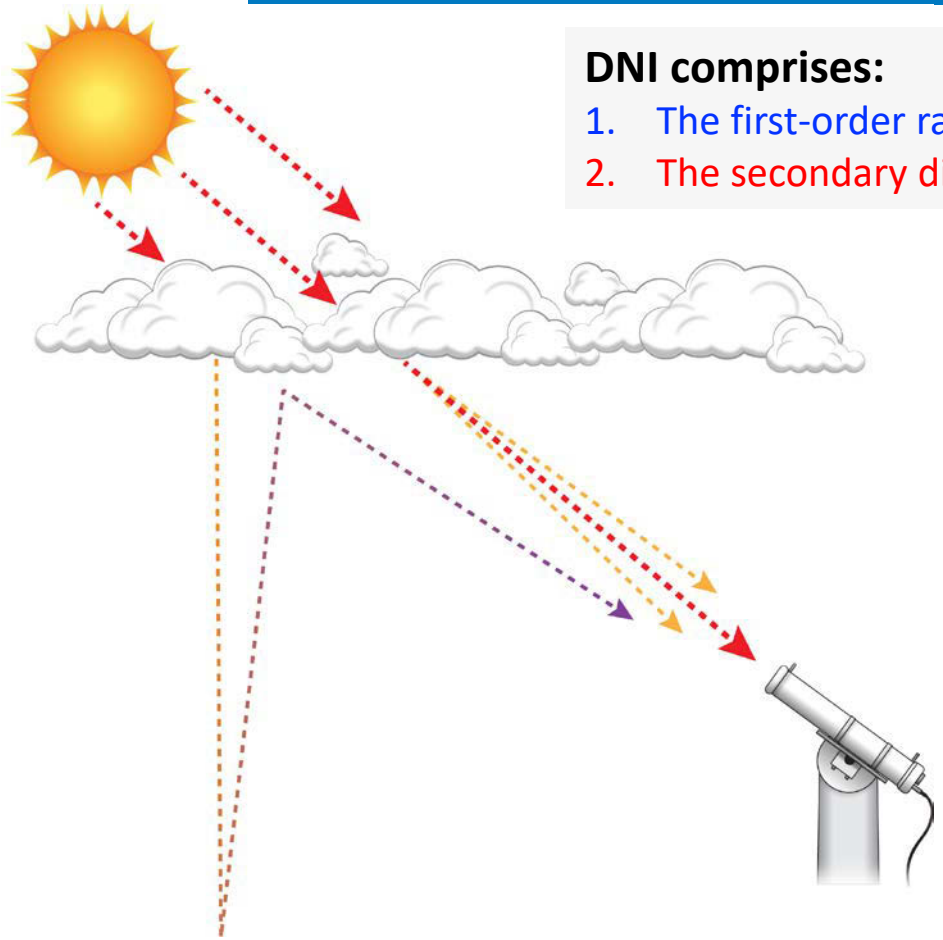
The transmittance of solar irradiance can be given by the integration of radiances over the differential solid angles.



FARMS-DNI

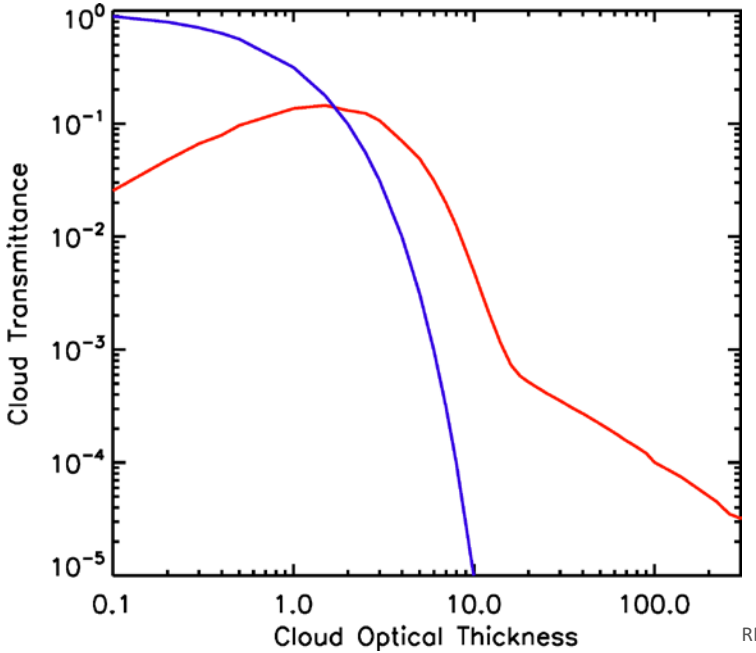

Clear Sky
Cloudy Sky
Atmospheric & Land Surface Properties
Clear-sky Radiative Transfer Model
Direct Normal Irradiance
Cloud Properties
Lookup Table of Cloud Transmittance
DISORT
Lambert Law
FARMS
Clear-sky Transmittance
Direct Normal Irradiance
Cloud Transmittance

FARMS-DNI



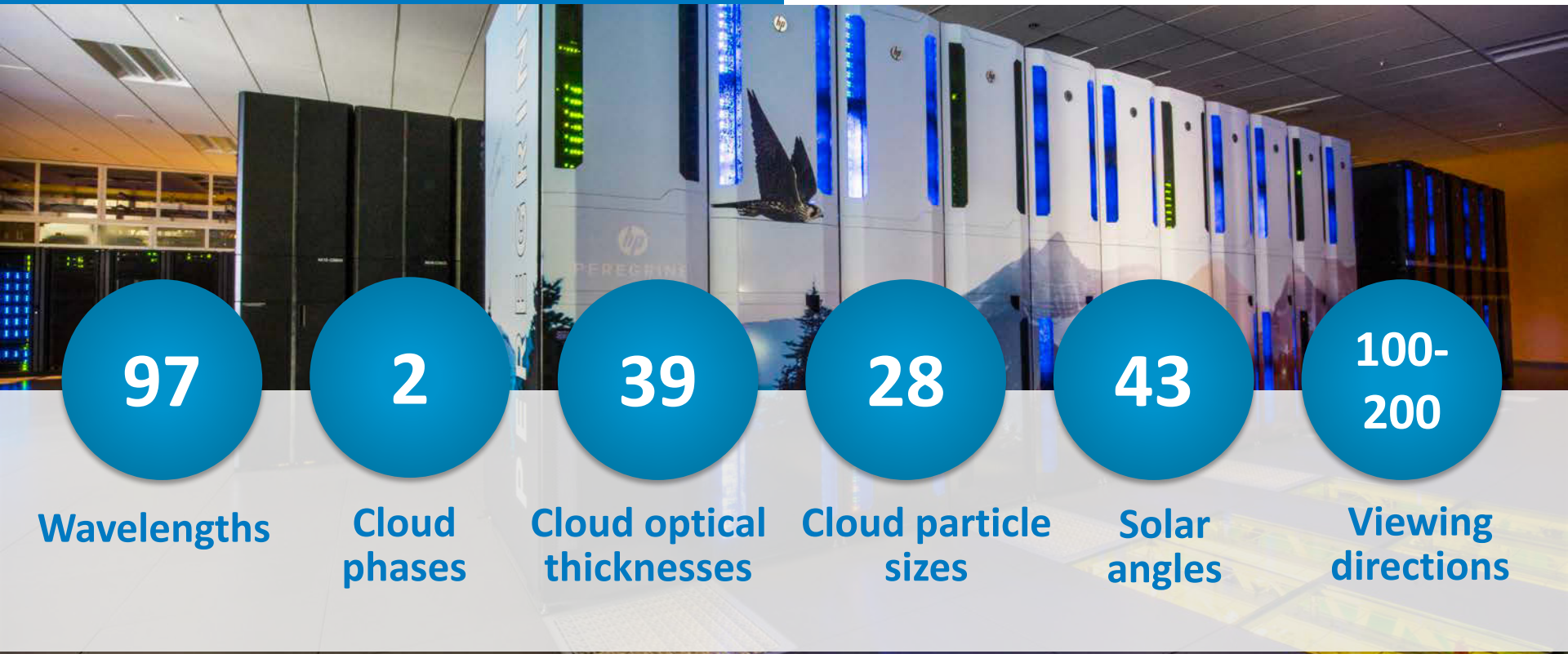
DNI comprises:

1. The first-order radiation within the circumsolar region.
2. The secondary direct radiation received by surface observations.



A Lookup Table of Cloud Transmittance

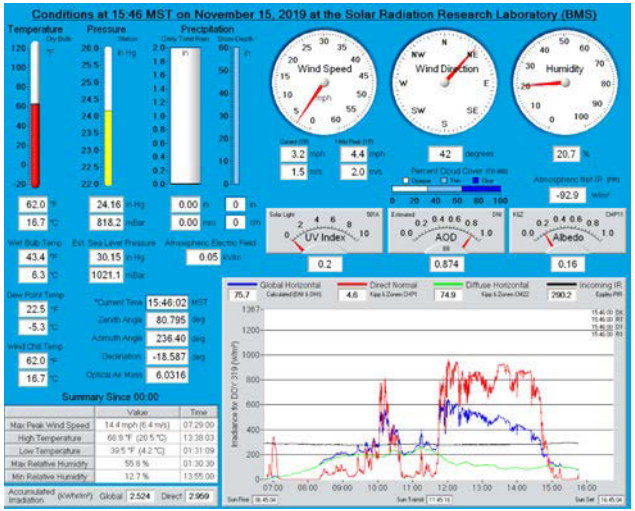
9.1×10^8 calculations, each takes ~1–2 seconds. **7,200–14,000 processor cores** were simultaneously utilized for **3 months**.



97	2	39	28	43	100-200
Wavelengths	Cloud phases	Cloud optical thicknesses	Cloud particle sizes	Solar angles	Viewing directions

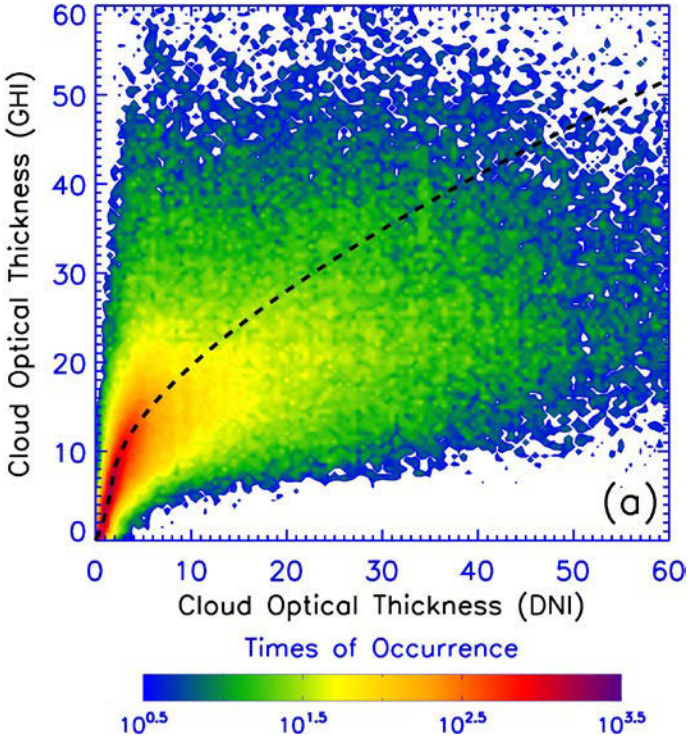
Photo by Dennis Schroeder, NREL 45373

Validation Data

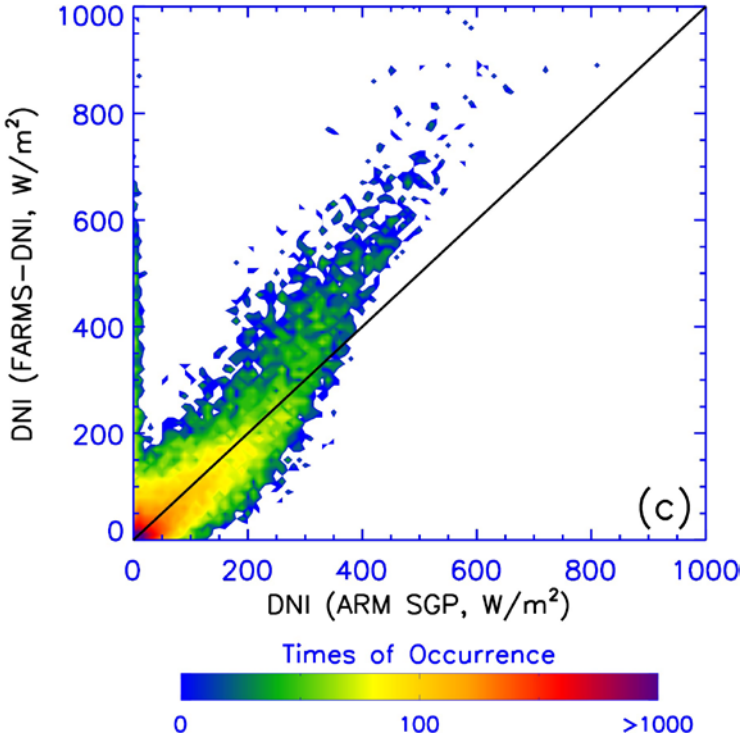


ARM Southern Great Plain site (Jan 1998-Dec 2014) and NREL's Solar Radiation Research Laboratory (**SRRL**) (Sep 2008-Dec 2017) data are selected for the test and evaluation of FARMS-DNI.

Validation

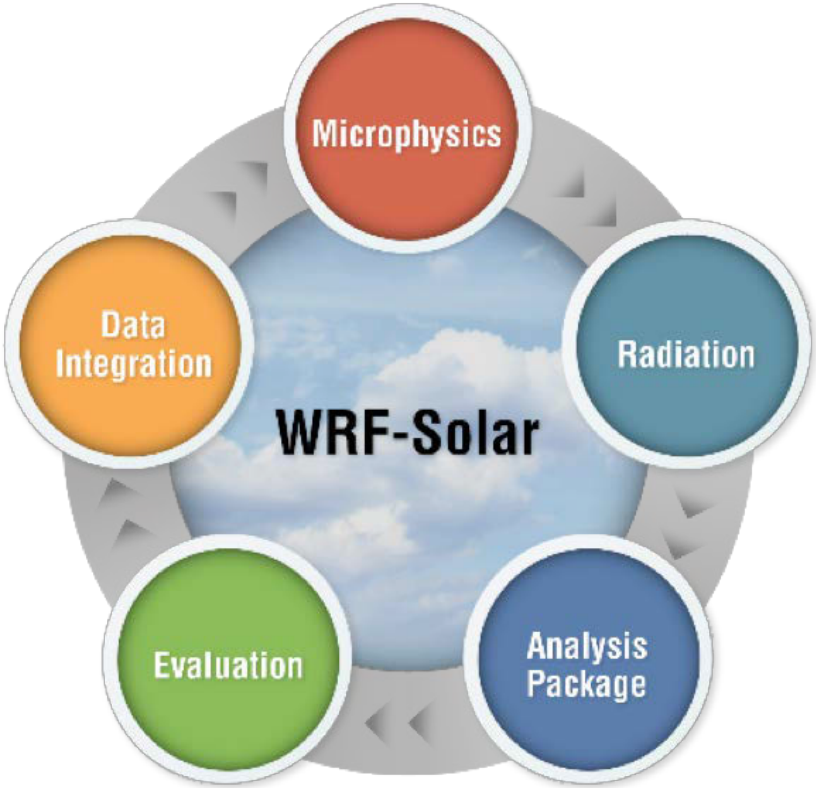


The retrieved cloud optical thickness by GHI is scaled to correct the computation of forward scattering.

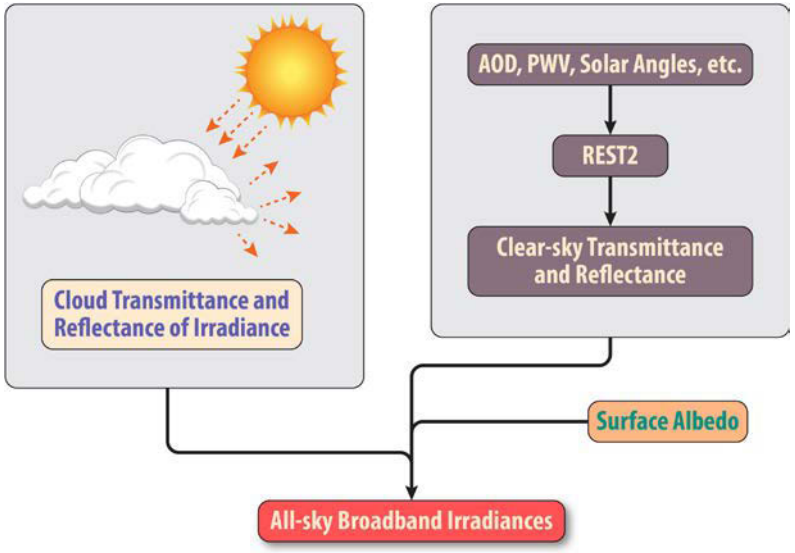


The uncertainty in the cloudy-sky DNI is reduced by a factor of **2–7!**

Applications in Solar Forecasting



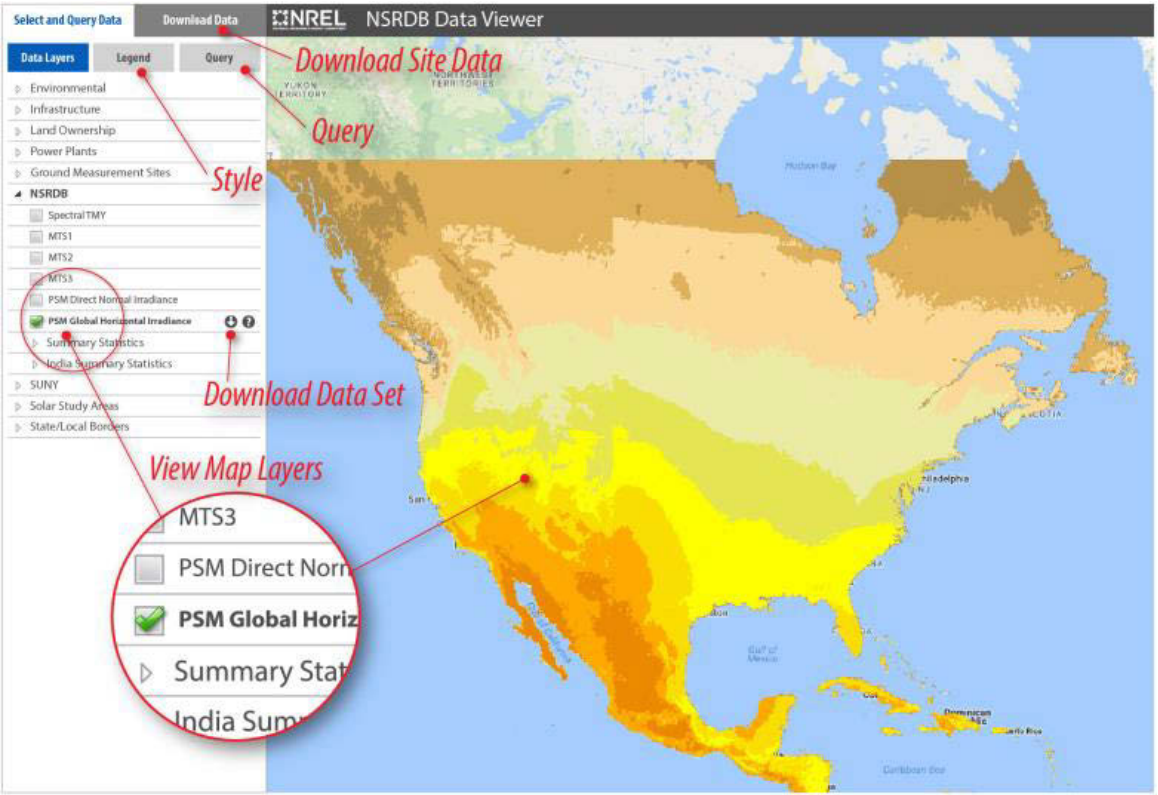
FARMS

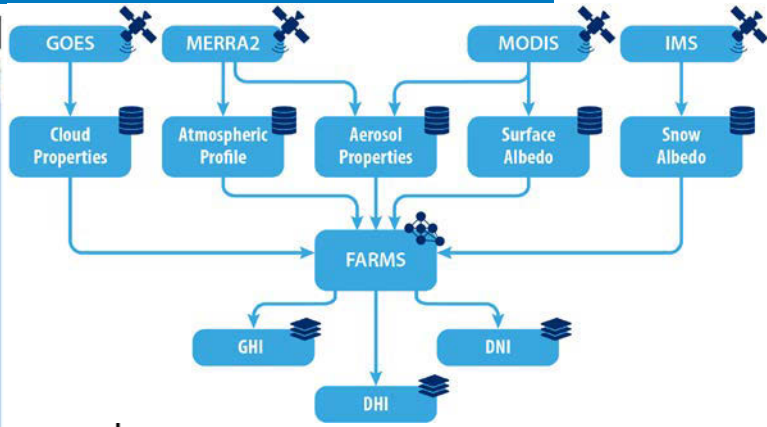


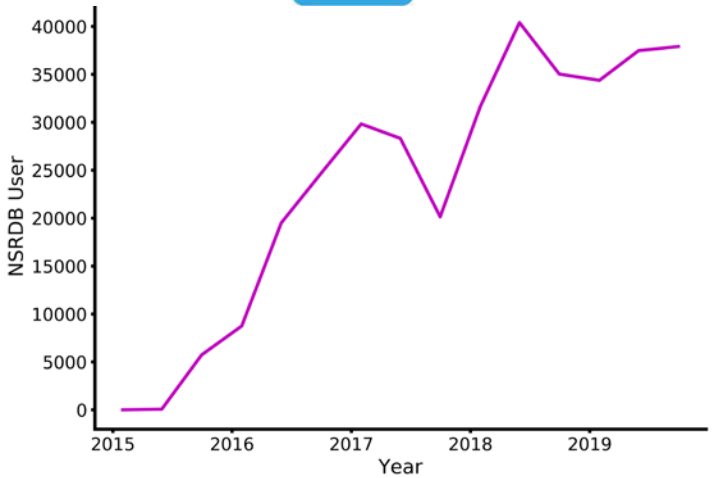
FARMS has been implemented to WRF-Solar to rapidly forecast global horizontal irradiance.

The FARMS-DNI interacts with FARMS to provide a more accurate DNI forecast.

Applications in Solar Resource Assessment







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